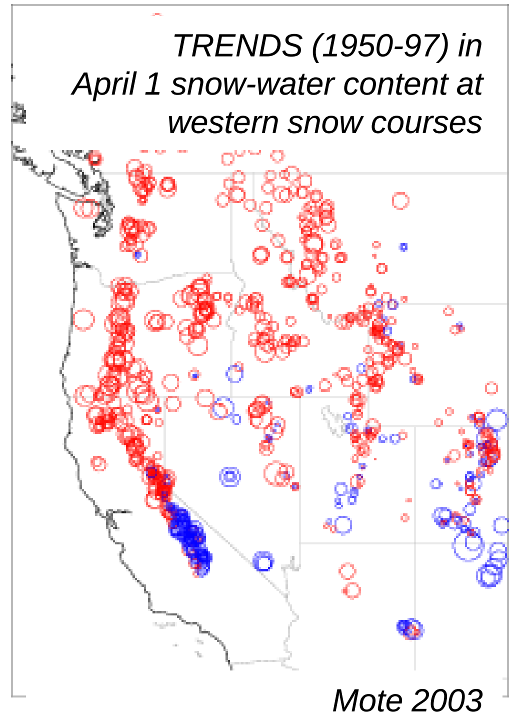
Can we detect climate change in western US hydroclimate?

Hugo Hidalgo[1], Tapash Das[1], David Pierce[1] Dan Cayan[1,2], Michael Dettinger[2,1], Tim Barnett[1], Govindasamy Bala[3], Andrew Wood[4], Celine Bonfils[3], Ben Santer[3], Art Mirin[3].

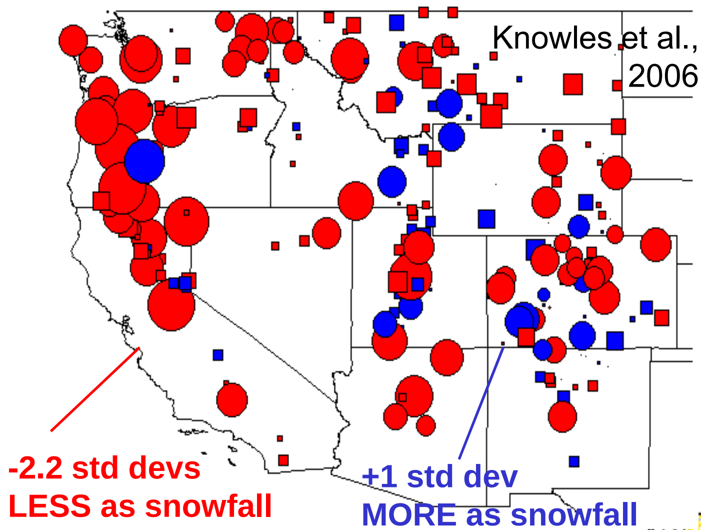
1) Scripps Institution of Oceanography
2) United States Geological Survey
3) Lawrence Livermore National Laboratory
4) University of Washington

Warming already has driven observable hydroclimatic change

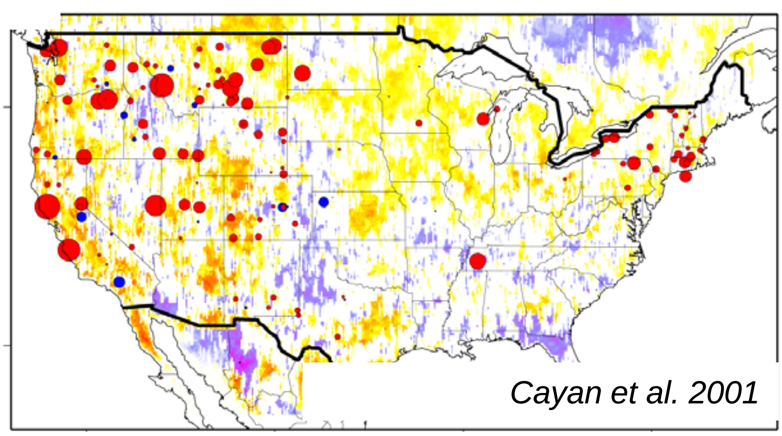
Observed: Less spring snowpa



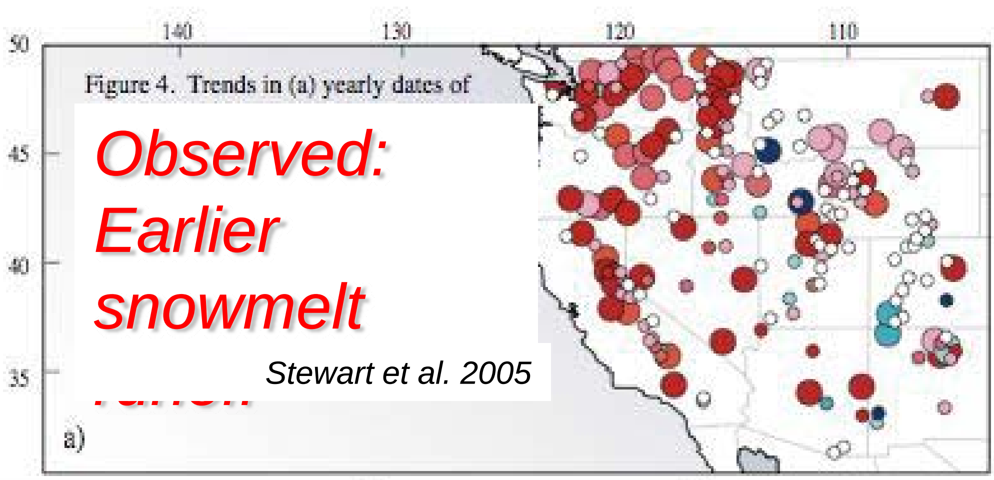
Observed: Less snow/more ra



Observed: Earlier greenup dates



Observed: Earlier snowmelt



Optimal detection & attribution

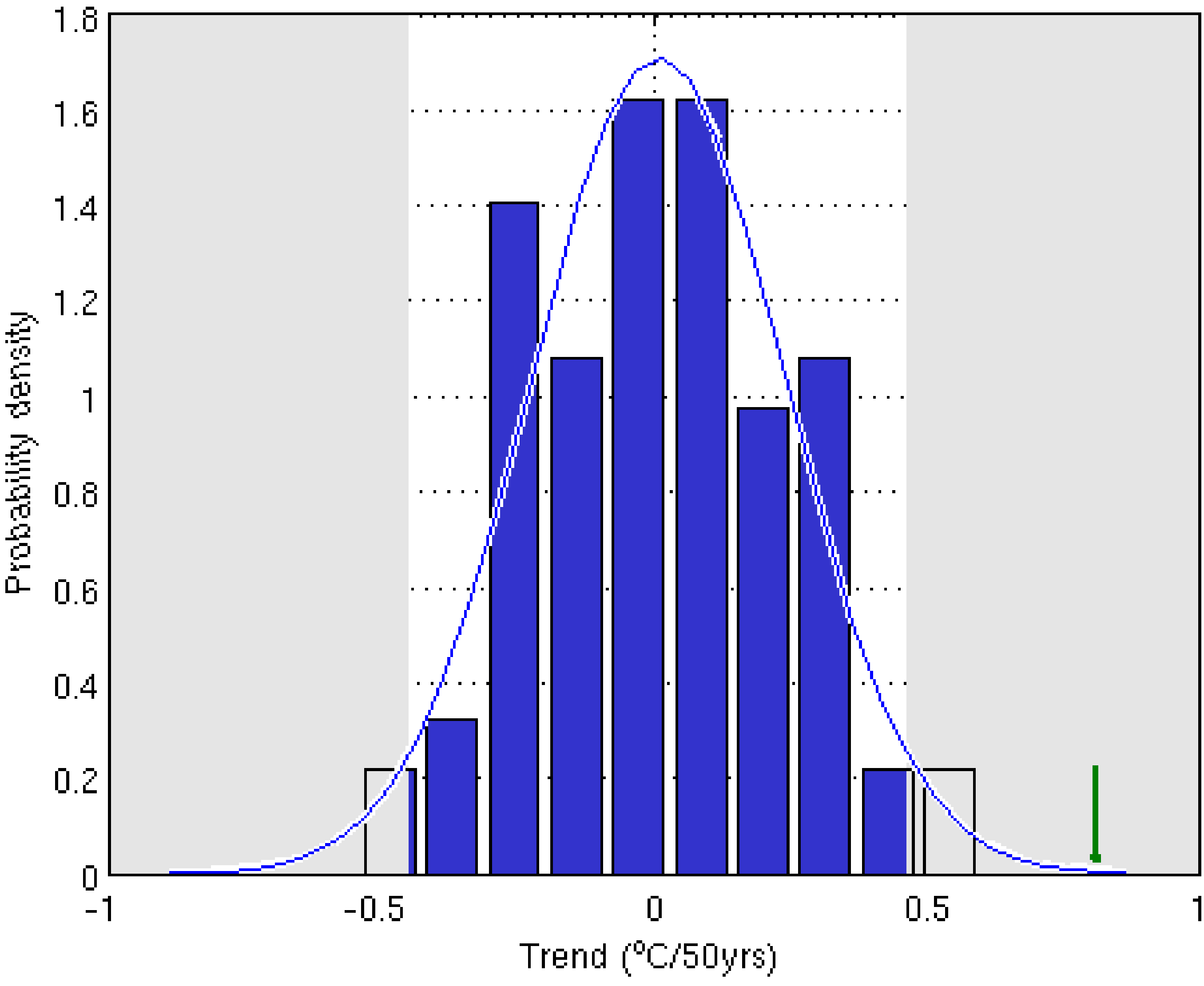
- *Detection* of climate change is the process of identifying if an observed change is significantly different from what would be expected from natural internal climate variability (Hegerl et al. 2006).
- *Attribution* of anthropogenic climate change is the process of identifying if the observed change is: a) consistent with the type of changes obtained from climate simulations that include external anthropogenic forcings and internal variability and b) inconsistent with other explanations of climate change (Hegerl et al. 2006).

Modeling

- Downscaled to 1/8 degree resolution using method of constructed analogues (CA) or bias correction followed by spatial desegregation (BCSD)
- Precipitation, tmax and tmin used as input to the variable infiltration capacity model (VIC; Liang et al. 1994)
- The VIC runoff and baseflow were routed using a computer program by Lohmann et al. (1996) to obtain daily streamflow data for the rivers
- Statistics were computed from the streamflow data

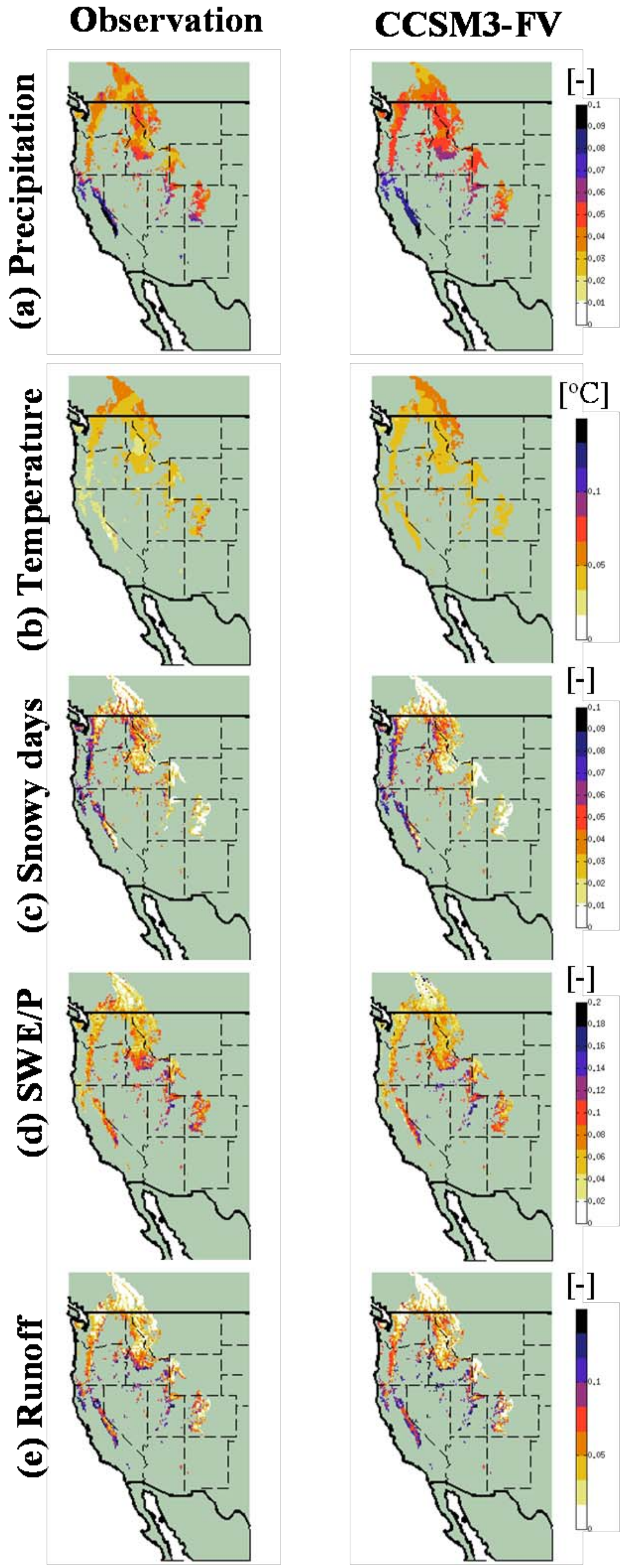
Detection on hydrological variables at high resolution

Detection

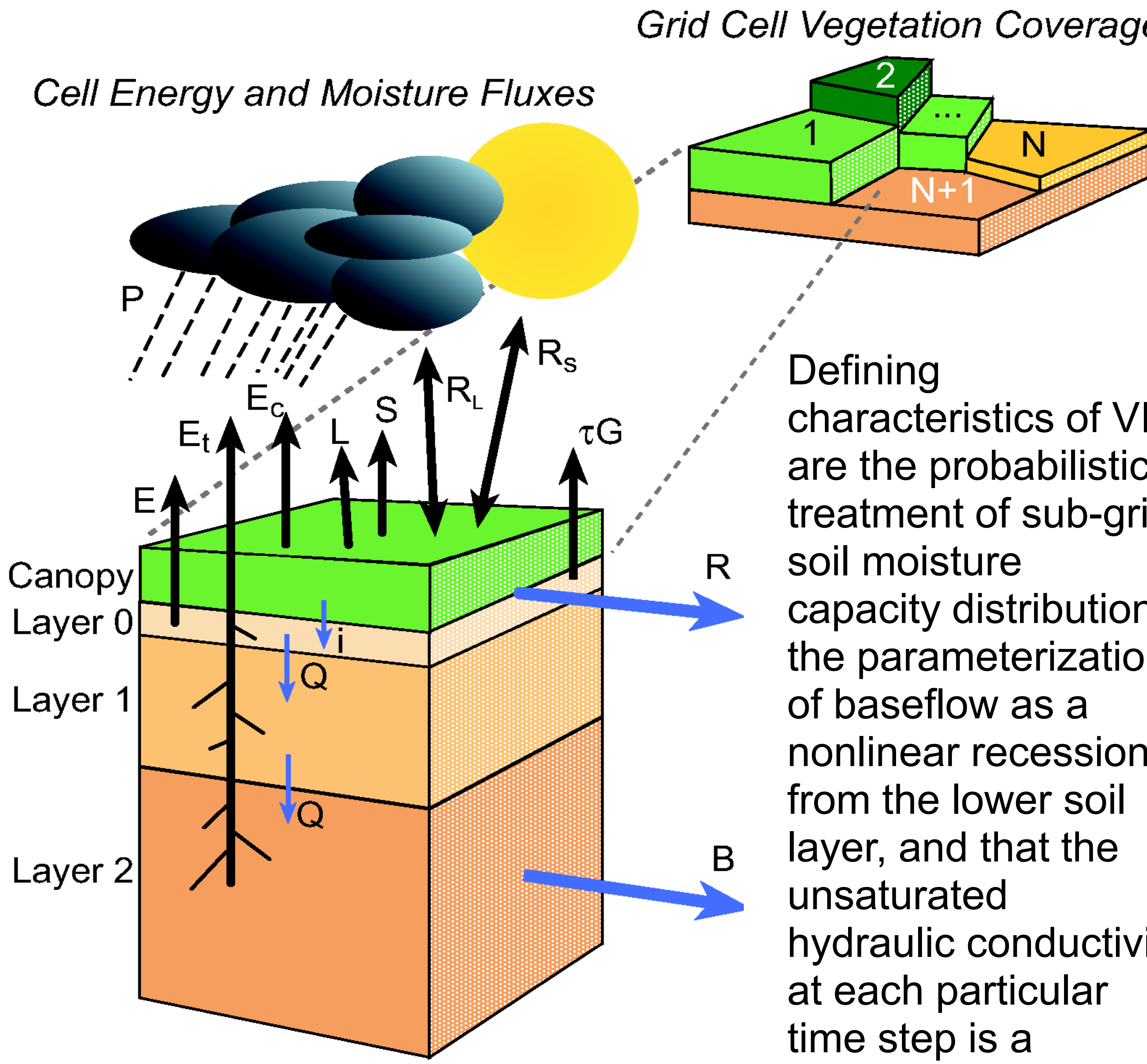


Probability density
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-1
-0.5
0
0.5
1
Trend (°C/50yrs)

5-year low pass filtered standard deviations

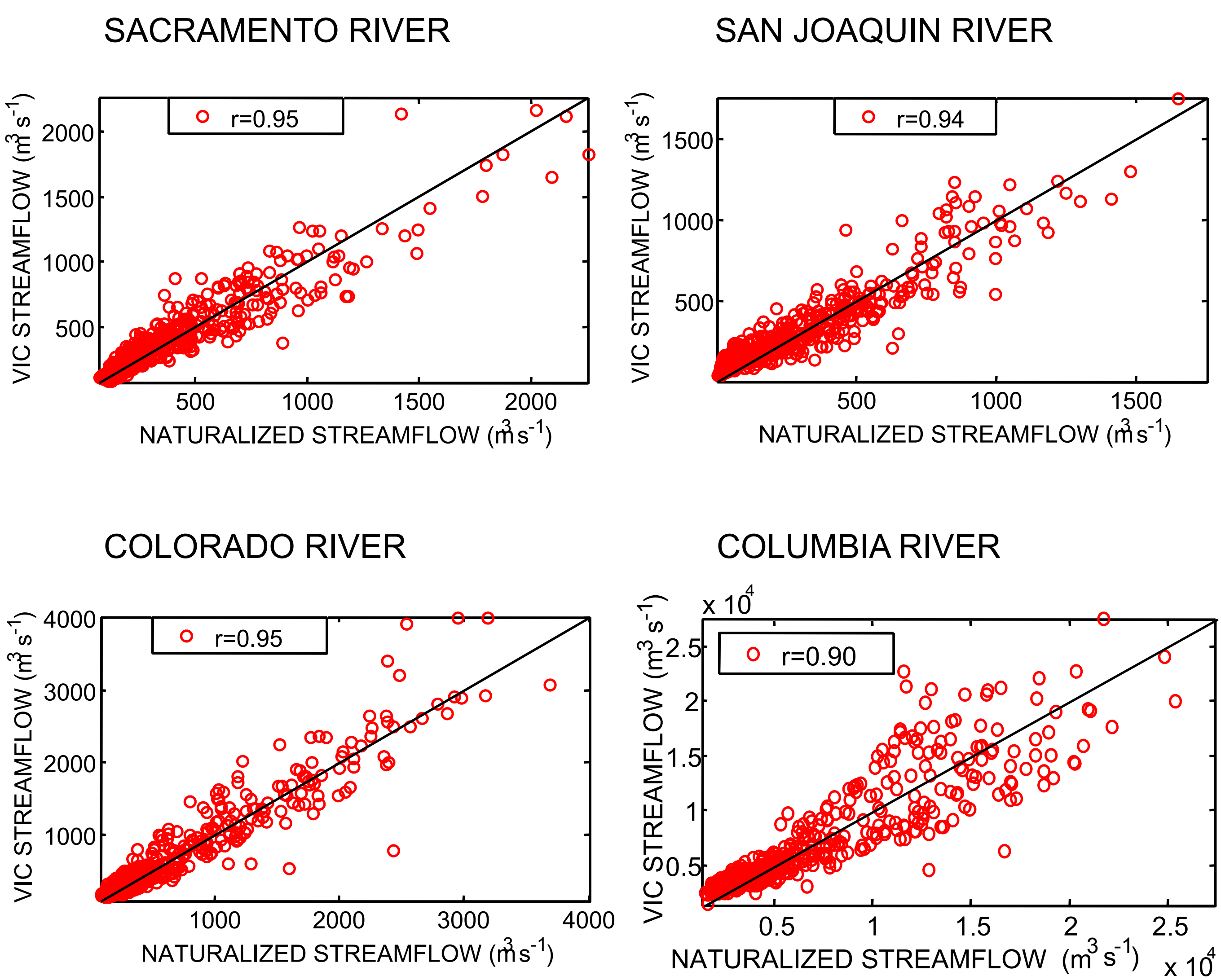


Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model

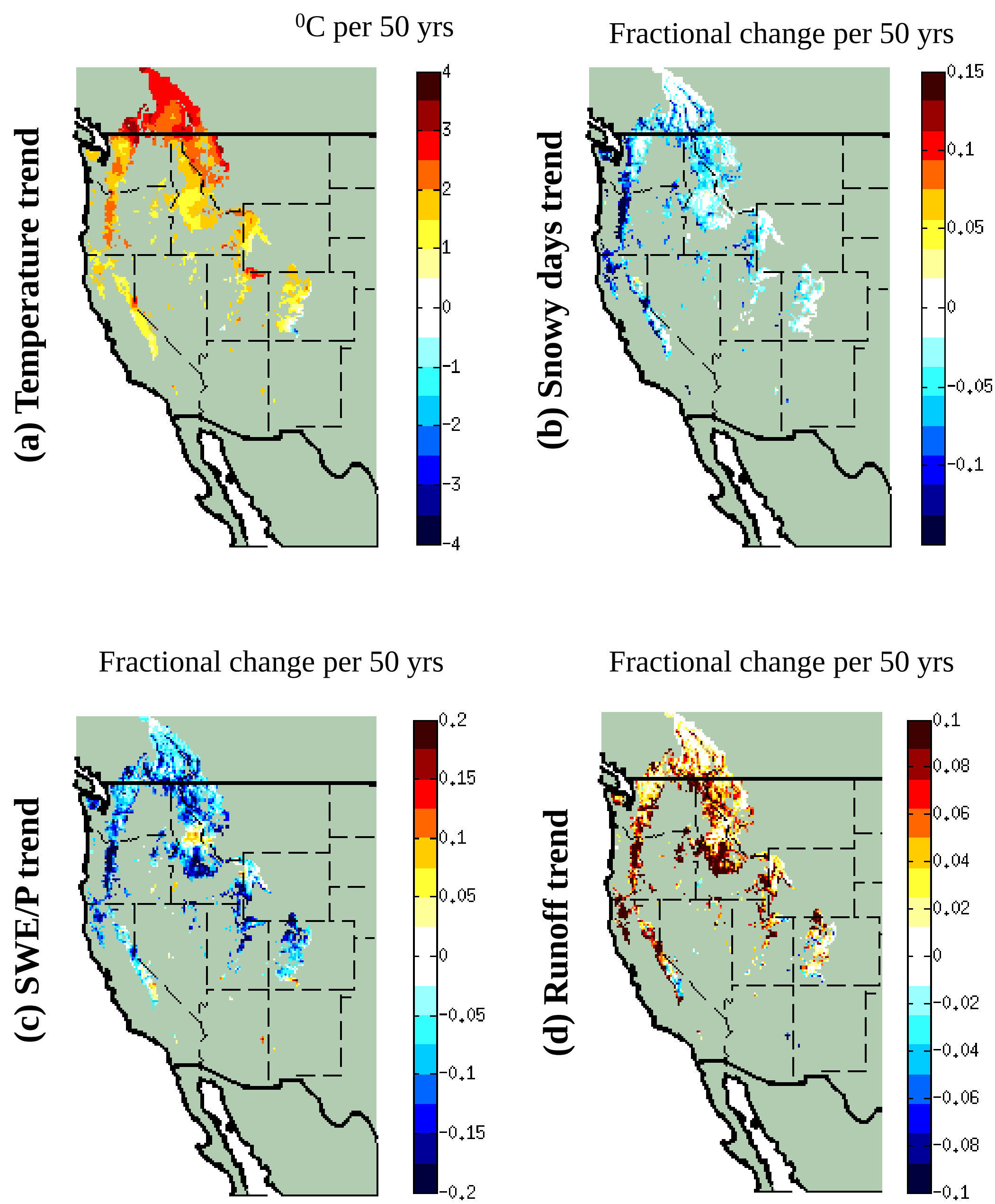


Defining characteristics of VIC are the probabilistic treatment of sub-grid soil moisture capacity distribution, the parameterization of baseflow as a nonlinear recession from the lower soil layer, and that the unsaturated hydraulic conductivity at each particular time step is a function of the degree of saturation of the soil (Sheffield et al. 2004; Campbell 1974; Liang et al. 1994)

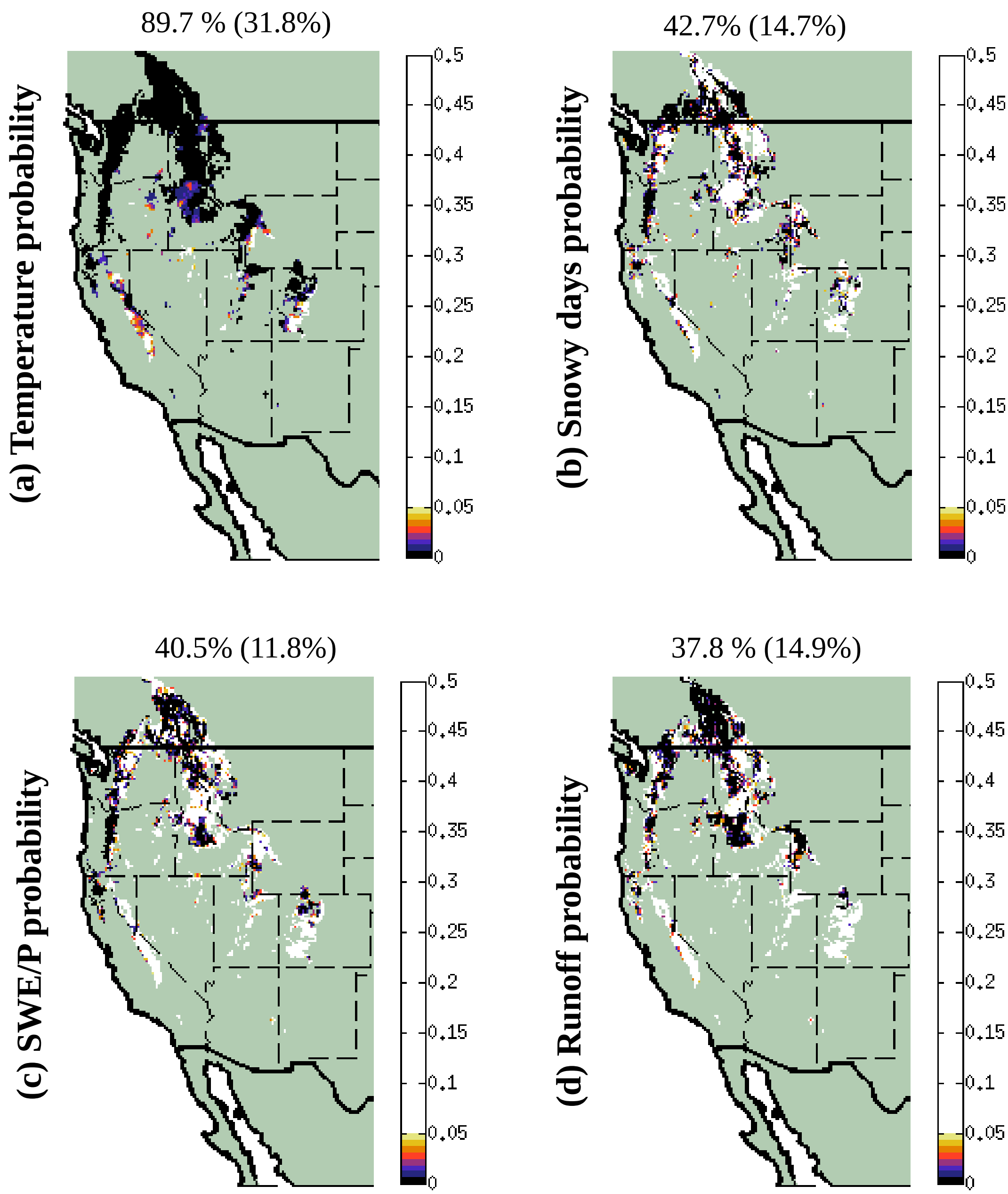
Comparison observed vs. modeled streamflow



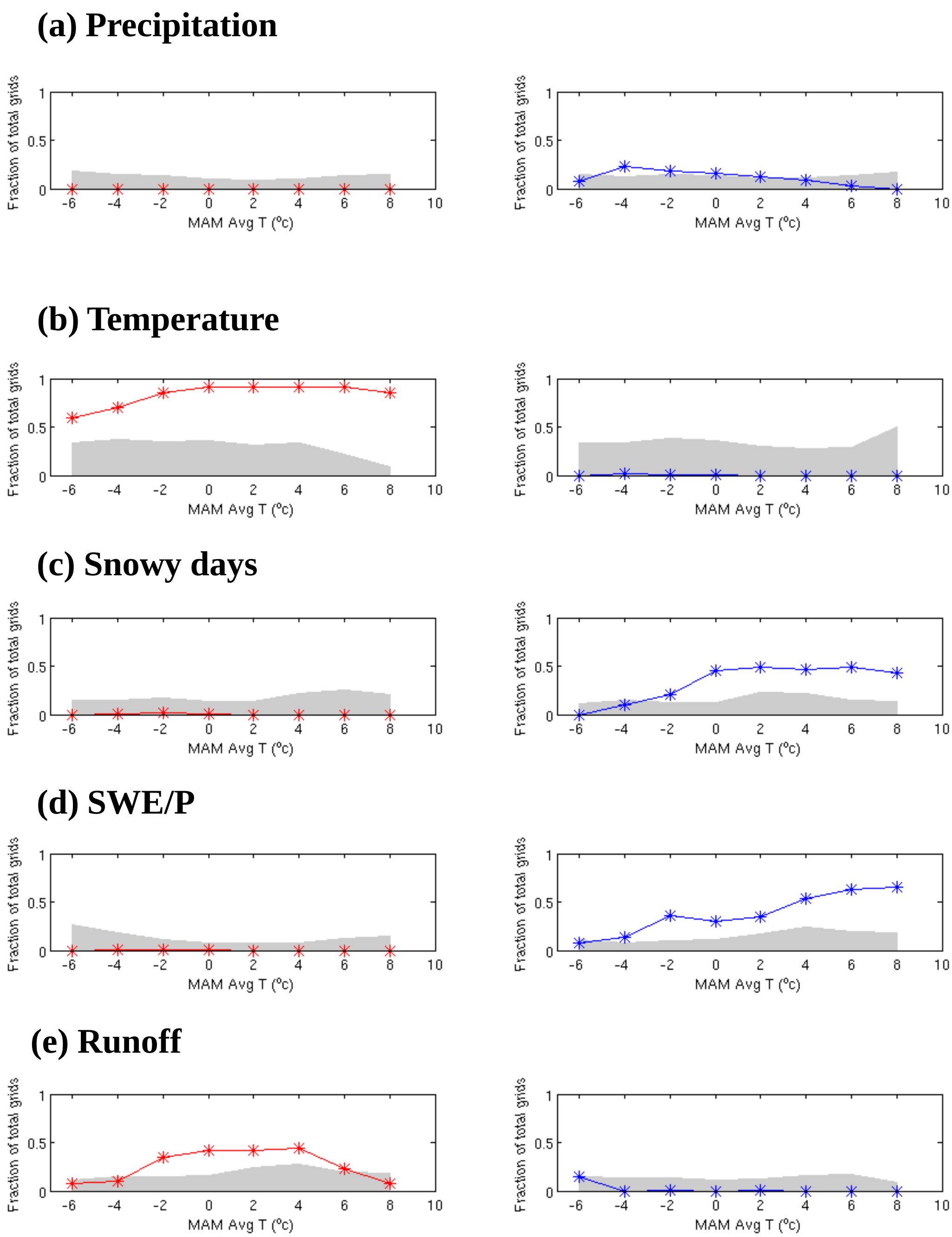
Trends in hydrological variables



Probabilities that the obs. trends are in the control run distribution



Temperature distribution of significant trends



% of grid-cells in each temperature class

MAM average temperature

Areas that contain the MAM average temperature at different specified intervals as a percentage of total area for three basins used in Hidalgo et al. (2008)

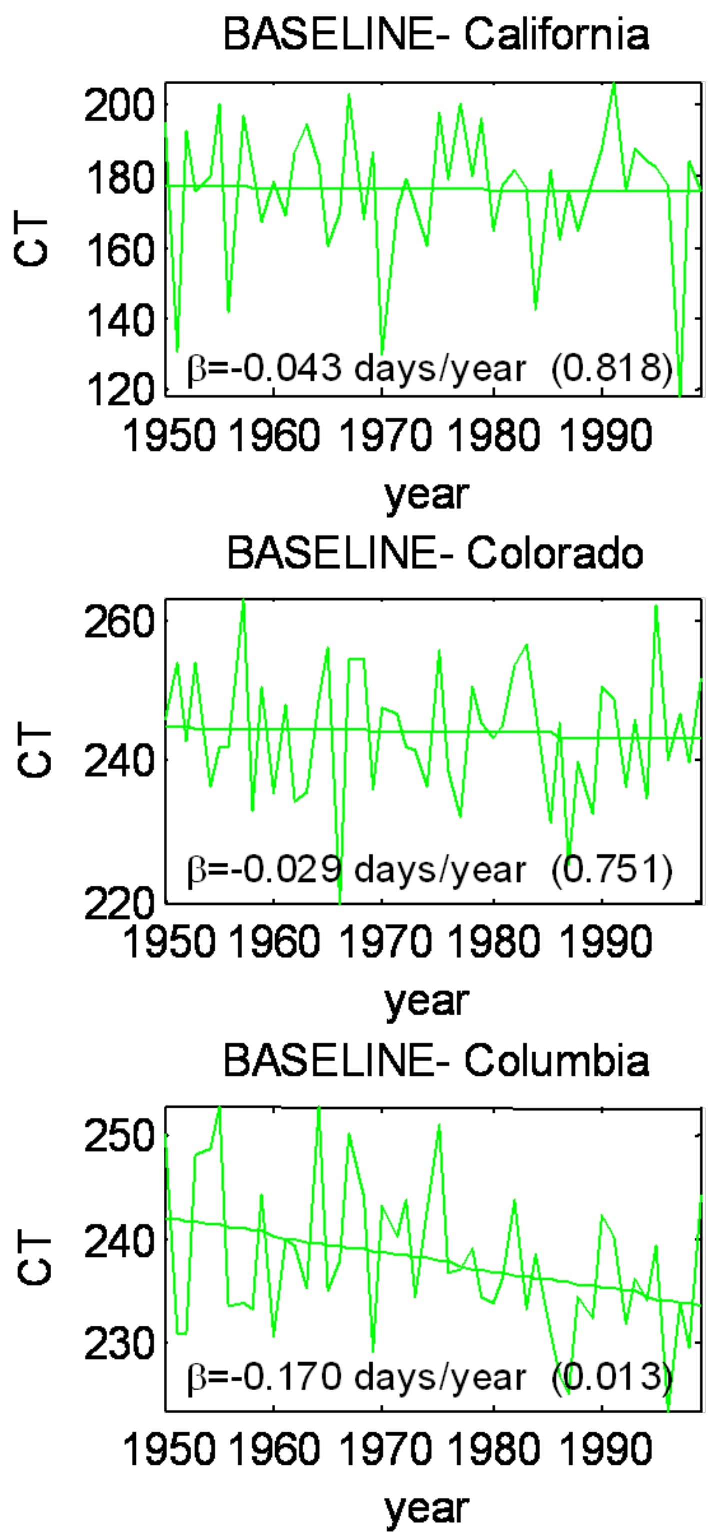
	California	Colorado at the Lees Ferry	Columbia at The Dalles
-20^oC to -10^oC	0.00	0.00	0.00
-10^oC to -2^oC	2.75	7.21	4.96
-2^oC to $+4^oC$	21.71	33.83	45.01
$+4^oC$ to $+20^oC$	75.54	58.95	50.03

Detection and Attribution on Center Timing of Streamflow

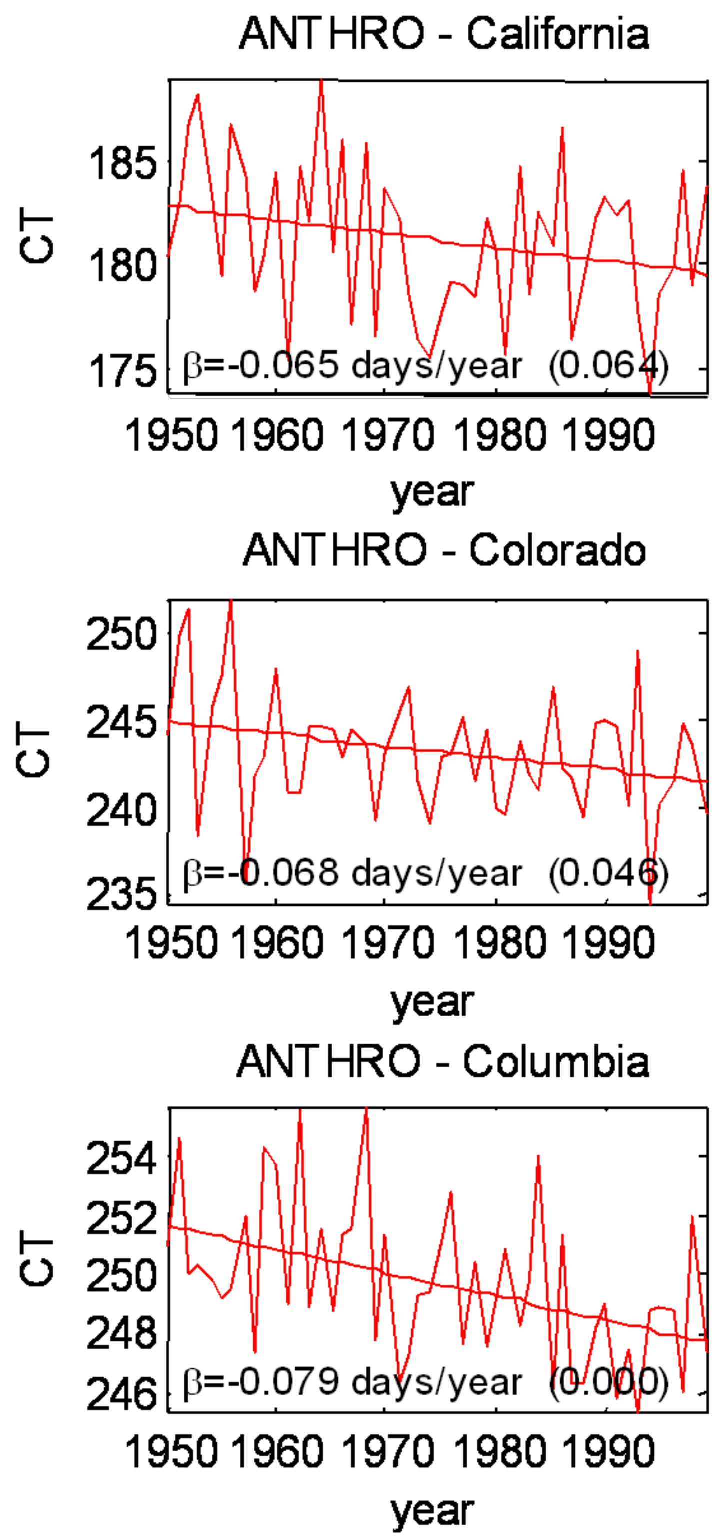
Models

- 850 years of control run CCSM3-FV downscaled using CA
- 750 years of control run PCM downscaled using BCSD
- Four realizations of 50 years each of anthropogenic forcing runs downscaled by BCSD
- Two realizations of solar and volcanic runs from the PCM downscaled using CA

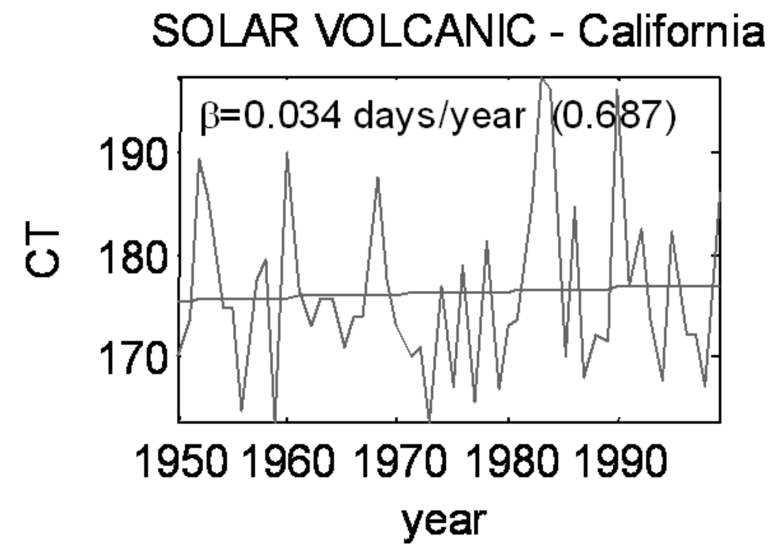
Observed trends

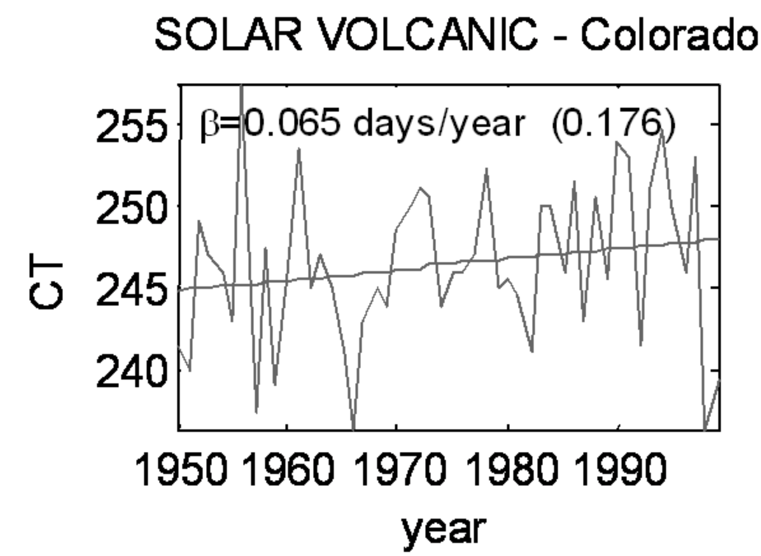


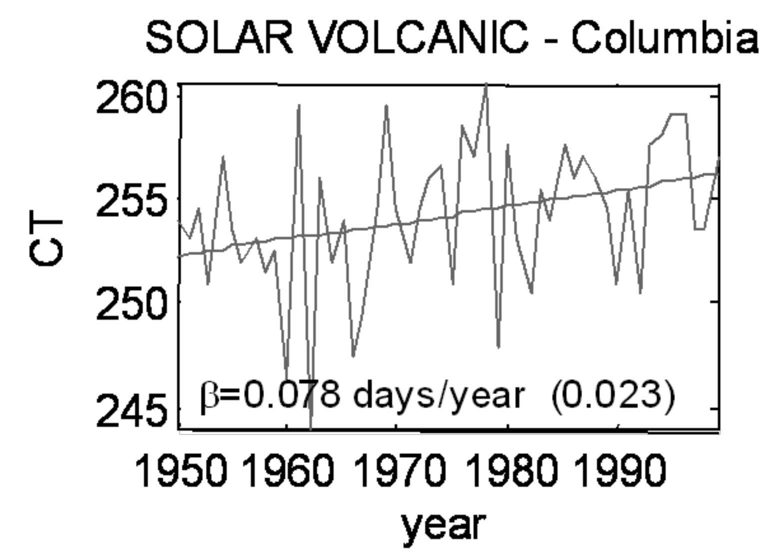
Anthro trends

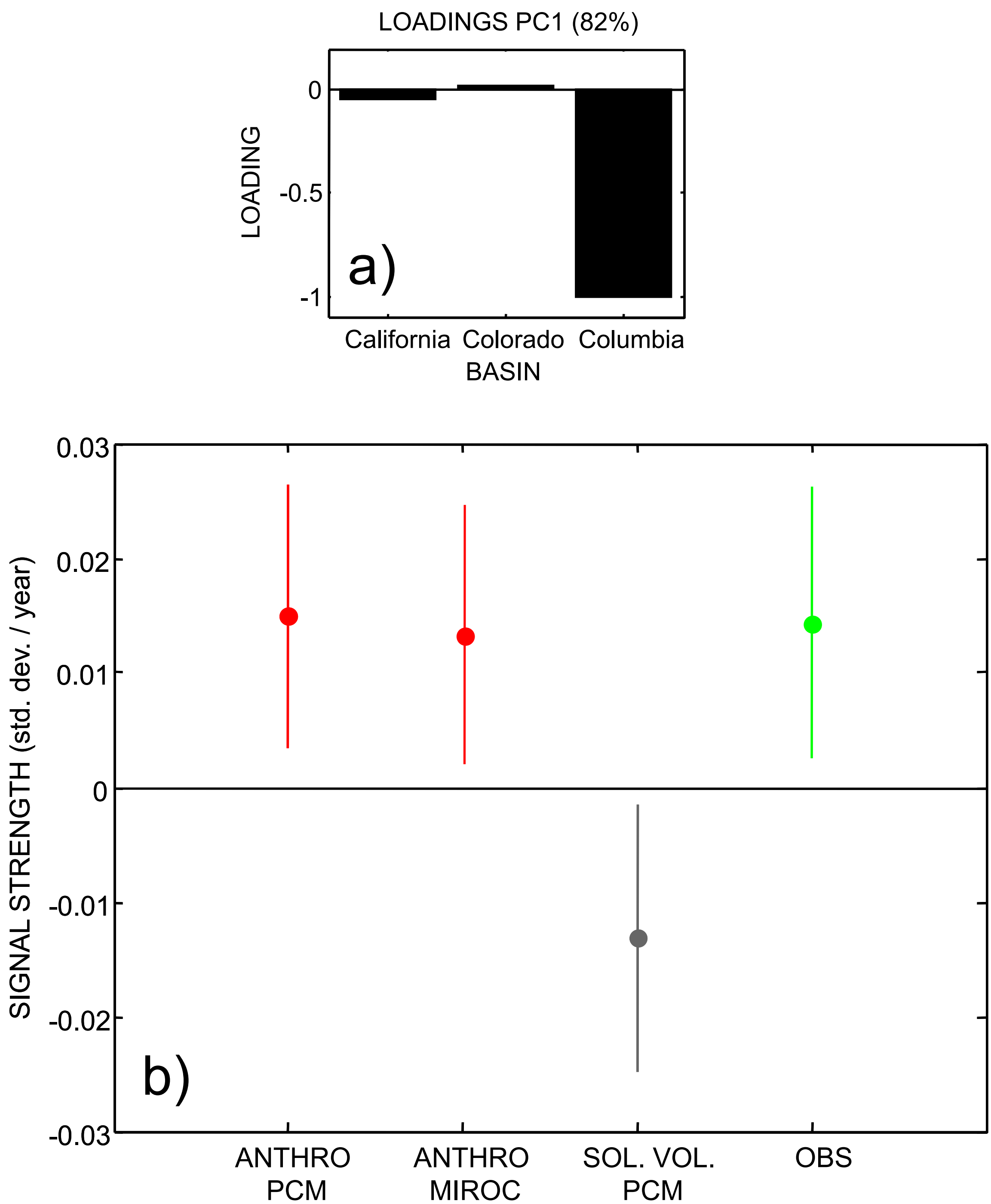


Solar Volcanic









$$S = trend\left(F(x) \bullet D(x,t)\right)$$

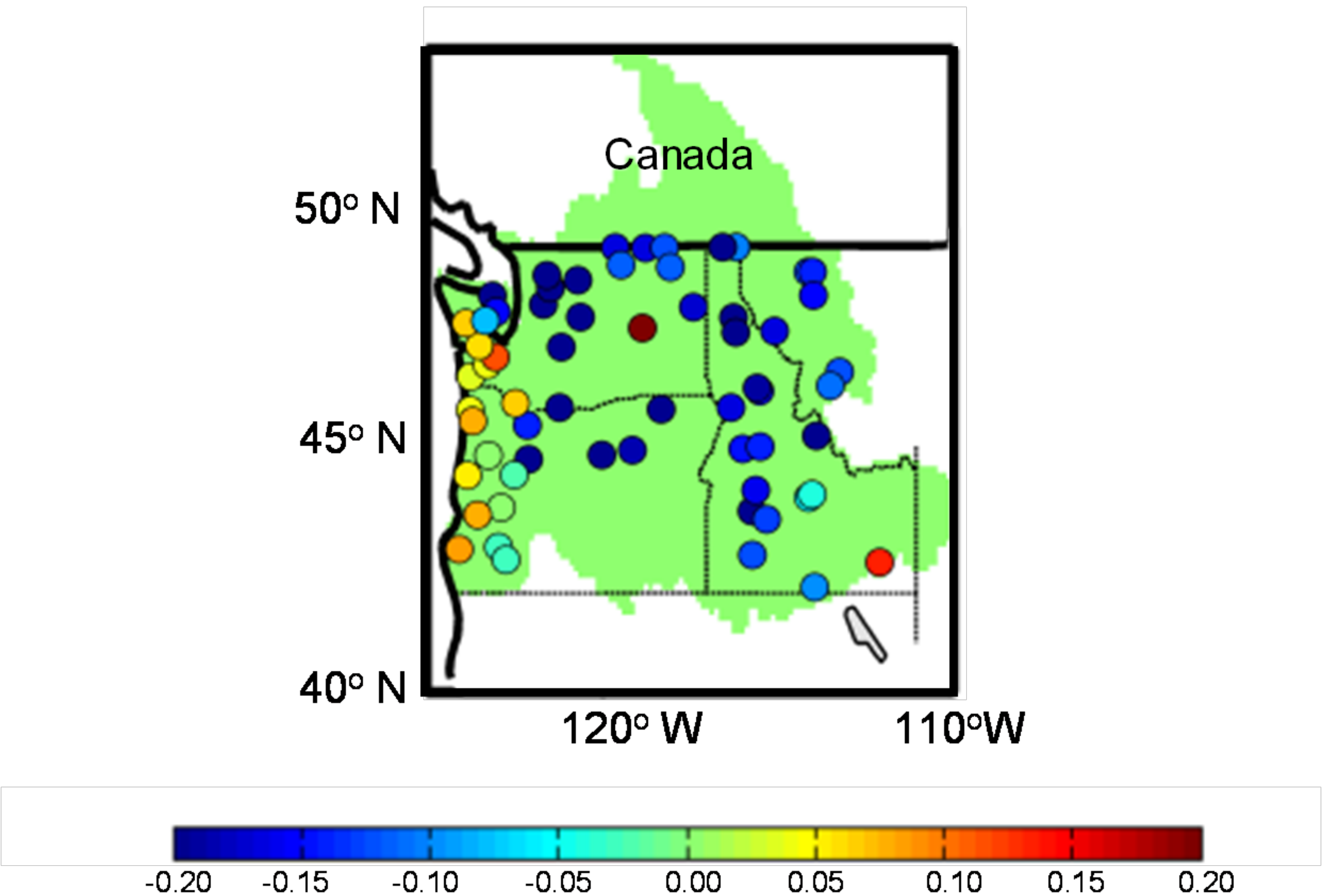
CONCLUSIONS

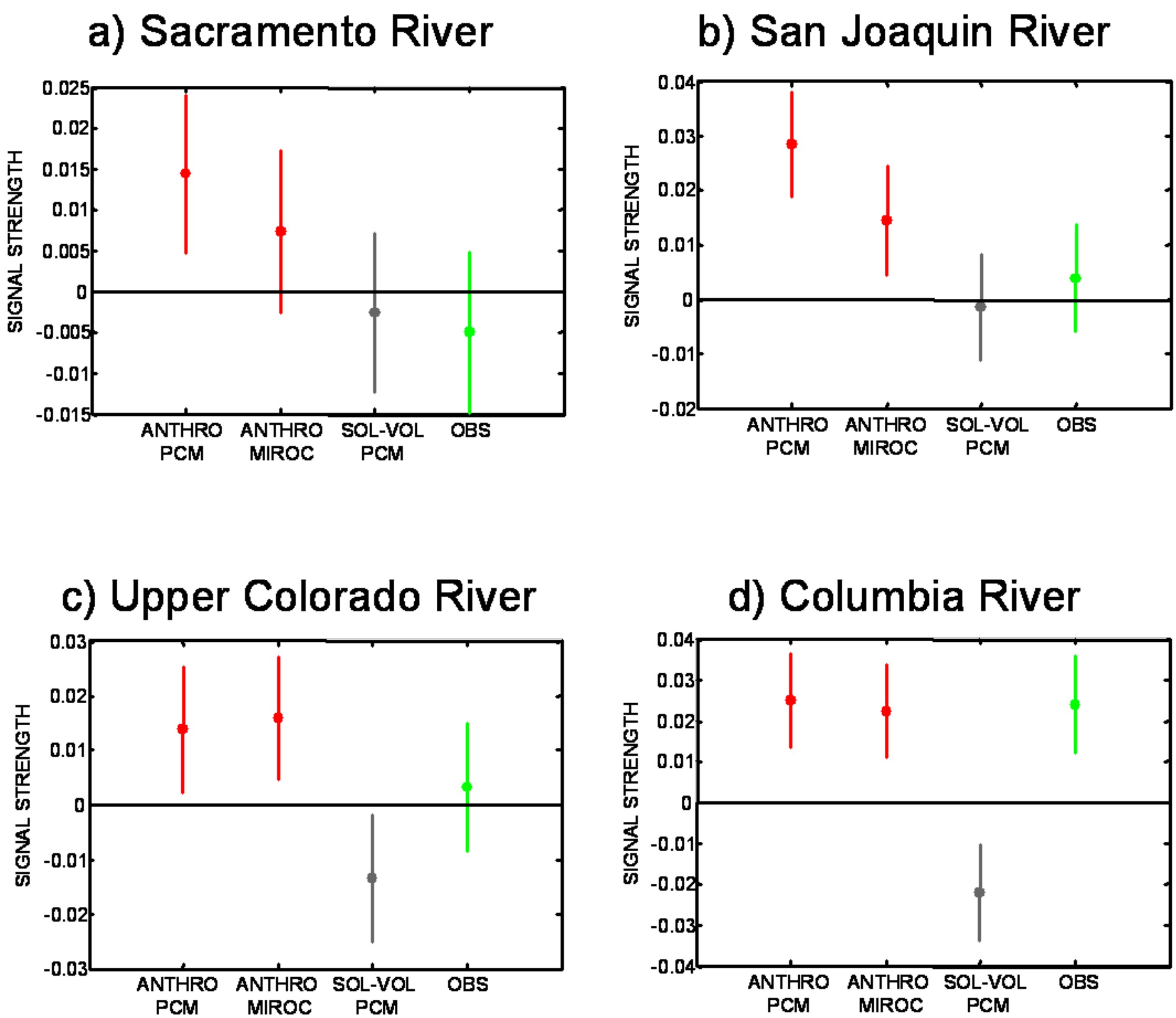
- Climate change signal was detected in several hydrological variables
- The Columbia river appears to be more vulnerable to climate change
- Detection *and attribution* of climate change was found for the CT.
- In general we find that anthropogenic greenhouse gases and sulphate aerosols have had a detectable influence on the seasonality of streamflow over the second half of the 20th century.

Acknowledgments

This research is supported by grants from the Lawrence Livermore National Laboratory and the California Energy Commission

CT trends (days/year)
Columbia basin





$$S = trend\left(F(x) \bullet D(x,t)\right)$$